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Greenhouse gas emission and renewable energy sources for sustainable development in Bangladesh

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ABSTRACT

Bangladesh is an energy starving country. The country will be on one of the fast growing power markets with its population and growing energy demand per person, its fast growing urbanization, and its socio-economic development. At present the potential demand of power is 5569 MW and the supply is below 4000 MW. The country is dependent on the imported petroleum that is big burden on the economy. The per capita emission is only 0.2667 tonne per person still much below the world leading countries (19.8 tonne per person for USA). However, Bangladesh is one of the most vulnerable to climate change effect in the world. In this regard, renewable energy resources appear to be the one of the most efficient and effective solution for clean and sustainable energy development in Bangladesh. Biomass is the dominating source of energy in Bangladesh. Biomass energy is used in a very traditional way. Biomass conversion to energy in the form of liquid, gaseous and solid pellet or briquette could be a viable option to reduce the pressure on the conventional fossil fuel. The geographical location of Bangladesh has several advantages for extensive use of grid connected solar electricity and stand alone solar PV system. This article presents a review of the potential and utilization of the renewable energy sources in Bangladesh.

Contents

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1. Introduction

Energy is the indicator of economic and social development and improved quality of life. Much of the world's energy currently used is produced from fossil sources and that is used in a way that could not be sustained if the alternative sustainable sources were explored and if the technology was remain constant [1]. Due to the use of fossil energy, extra million tonne of greenhouse and other gases are increasing substantially to make the earth unstable. Climate change is one of the most difficult challenges facing the world today. Burning fossil fuel such as gas, oil and coal provides about three-fourth of world's energy. When these fuels are burned, they emit greenhouse gases (GHGs) that are now recognized as being responsible for climate change. The primary greenhouse gas emitted through fuel combustion is CO_2. Land-use and land-use changes, notably deforestation, also involve emissions of CO_2 [2]. Bangladesh has only commercial energy natural gas that mainly supports power generation in the country at present. More than 80% of power generation is dependent on it. As per the forecast of Petrobangla, the total remaining gas reserve (July 2005) of 13.75 Tcf would meet the country's projected energy demand up to 2015. After that, each year, there will be short supply of gas and this would increase to 4421 MMcfd by 2025. This means that to support the projected energy demand, 8.35 Tcf of additional gas would be required. This short supply of gas would have to be managed either by discovery of additional gas field or alternative sources of fuel. Presently known primary commercial energy resource includes natural gas, oil including condensate, coal and hydroelectricity. In the past peat was considered as a source but detail study that exploitation of high quality coal negates its possibility to use it as commercial energy resource. Biomass still plays an important role in country's energy consumption. Till now nuclear energy is not given any serious thought. In 2003, the per capita energy consumption was estimated to be 220 kg of oil equivalent. Biomass is the dominant energy source used as a source of thermal energy in domestic, commercial and industrial sectors in Bangladesh. Per capita emission of greenhouse gas for Bangladesh in terms of CO_2 equivalent is less than a tonne per year, if traditional biomass burning is excluded. Total greenhouse gas emission of the country was 13.44 million tonne of CO_2 equivalent in 1990 [3]. This paper gives an overview of the status of GHG emission and renewable energy worldwide and in Bangladesh.

2. Global GHG emission and renewables

2.1. GHG emission

GHG emission is of course the reason why there is a need to avoid producing CO_2. The gas like CO_2 allows the suns ray in but stop the heat radiation form re-emerging, much as happens with glass in greenhouse. The result is that the greenhouse gas heats up the whole world. However, the extra million tonne of CO_2 gas we released in the atmosphere seems like to upset the natural balance. World energy-related carbon dioxide emissions grow from 29.7 billion metric tonne in 2007 to 33.8 billion metric tonne in 2020 and 42.4 billion metric tonne in 2035. Table 1 shows world CO_2 emission by region. The increasing trend of world emission is more in the developing countries compared to developed country although the per capita emission is much lower in the developing countries. Therefore the developing countries should be more careful to use energy in future for minimizing the global emission. World energy-related carbon dioxide emissions increase by an average of 1.3% year from 2007 to 2035.

Another indicator of carbon dioxide intensity is emissions per person. Carbon dioxide emissions per person in organization for economic co-operation and development (OECD) economies are significantly higher than in non-OECD economies (Table 2). China has the highest percentage increase in carbon dioxide emissions per capita of 4.7 tonne per person in 2007 and 9.2 tonne per person in 2035. OECD countries have higher levels of carbon dioxide emissions per capita, in part because of their higher levels of income and fossil fuel use per person. US emissions per capita fall from 19.8 tonne in 2007 to 16.2 tonne in 2035 but remain highest per capita emission in the world. Income per capita is the most important determinant of carbon dioxide emissions per capita, but other factors for example, climate and population density also affect the calculation.

2.2. Renewable energy sources

World energy use continues to be at the center of the climate change debate due to the anthropogenic emissions of carbon dioxide result primarily from the combustion of fossil fuels. Sustainable energy is only concern of mitigating the anthropogenic emissions. Renewable energy instead of fossil energy is identified is only the sustainable energy to stable future earth. Renewable energy supplies 18% of the world's primary energy, counting traditional biomass, large hydropower and new renewables such as small hydro, modern biomass, wind solar, geothermal and biofuels. Traditional biomass is primary used for cooking in the developing countries and space heating at cold region, represents about 9% and is growing slowly or even declining some regions as biomass energy is used more efficiently or replaced by more modern energy form. Hydropower is the highest installed capacity amounting 980 GW and growing slowing, mainly in developing countries. New renewables are 2% and growing very fast in developed countries and some developing countries. The world's renewable energy status is shown in Table 3. The fasted growing energy technology in the world has been grid-connected solar PV, with total existing capacity increasing from 0.16 GW at the start of 2000 to 13 GW by the end of 2008. During the same time, other renewable energy technologies grew rapidly as well: wind power, biodiesel, solar hot water/heating, off-grid solar PV, geothermal heat capacity and ethanol.

3. Energy utilization and environmental issues in Bangladesh

3.1. Energy utilization

Bangladesh is an energy starving country; about 47% of total commercial energy requirement is supplied by imports [6]. The imported petroleum is mainly consumed by the transport sector and agriculture sector (land cultivation and irrigation). A share of imported petroleum is consumed electricity generation. Gas is the biggest share of total primary energy consumption. About 70% of power generation is dependent on it. As per the forecast of Petrobangla, the total remaining gas reserve (July 2005) of 13.75 Tcf would meet the country's projected energy demand up to 2015. The final energy production and consumption scenario of Bangladesh are shown in Tables 4 and 5.

3.2. Electricity generation

The electricity energy is deficit in Bangladesh as per demand. The total installed capacity of electric power is increased from 2350 MW in 1990 to 5823 MW in 2010, with an annual growth rate of 5.17% (Fig. 1). The grid electricity is generated from four main sources:

Table 1
Carbon dioxide emission in the World by region (1990–2035) (billion tonne).

Region	History		Projections					Average annual percentage change	
	1990	2007	2015	2020	2025	2030	2035	1990–2007	2007–2035
OECD countries	11.5	13.7	13.0	13.1	13.5	13.8	14.2	1.0	0.1
North America	5.8	7.0	6.7	6.9	7.2	7.4	7.7	1.1	0.3
Western Europe	4.2	4.4	4.1	4.0	4.0	4.1	4.1	0.3	−0.2
Asia	1.6	2.3	2.1	2.2	2.3	2.3	2.4	2.1	0.2
Non-OECD countries	10.0	16.0	18.5	20.7	23.0	25.5	28.2	2.8	2.0
Europe and Eurasia	4.2	2.9	2.9	2.9	3.0	3.0	3.2	−2.2	0.3
Asia	3.7	9.4	11.2	13.0	14.9	16.9	19.0	5.7	2.5
Middle East	0.7	1.5	1.9	2.1	2.3	2.5	2.7	4.6	2.1
Africa	0.7	1.0	1.2	1.2	1.3	1.5	1.6	2.6	1.7
Central and South America	0.7	1.2	1.3	1.4	1.5	1.6	1.7	3.1	1.4
Total World	21.5	29.7	31.5	33.8	36.5	39.3	42.4	1.9	1.3

Source: [23].

Table 2
Carbon dioxide emission per capita in the World by region (tonne per person).

Region	History		Projections					Average annual percentage change	
	1990	2007	2015	2020	2025	2030	2035	1990–2007	2007–2035
OECD countries	11.0	11.6	10.5	10.4	10.4	10.5	10.6	0.3	−0.3
North America	16.0	15.8	14.1	13.8	13.7	13.6	13.5	−0.1	−0.6
United States	20.0	19.8	17.5	17.1	16.8	16.5	16.2	−0.1	−0.7
Canada	17.0	17.8	15.4	14.7	14.6	14.7	14.8	0.3	−0.7
Mexico	3.6	4.1	3.9	4.2	4.5	4.9	5.5	0.8	1.0
Western Europe	8.4	8.1	7.4	7.2	7.1	7.1	7.1	−0.2	−0.5
Asia	8.5	11.4	10.6	10.9	11.3	11.7	12.2	1.7	0.2
Non-OECD countries	2.4	2.9	3.1	3.3	3.5	3.7	4.0	1.3	1.1
Europe and Eurasia	12.3	8.5	8.5	8.7	8.9	9.3	9.8	−2.1	0.5
Asia	1.3	2.7	2.9	3.2	3.6	3.9	4.3	4.2	1.7
Middle East	5.2	7.5	8.4	8.5	8.5	8.5	8.8	2.2	0.6
Africa	1.0	1.0	1.1	1.0	1.0	1.0	1.1	0.1	0.1
Central and South America	1.9	2.5	2.6	2.6	2.7	2.8	2.9	1.6	0.4
Total World	4.1	4.5	4.3	4.4	4.6	4.8	5.0	0.5	0.4

Source: [23].

gas 4822 MW, diesel/oil 522 MW, coal 250 MW and hydropower 230 MW. The biggest share of electricity comes from gas generation system. The power plants are not operated for maximum output due to the shortage of fuel. The rate of gas production capacity is declining day by day. The country economy situation could not permit to import more petroleum for power generation. The big hydropower plant could not run at full capacity due to declination of water head at lake. However the demand of electricity is increasing day by day due to the growth of industry and population. To keep this in mind the alternative and renewable energy sources are coming forward. The off-grid solar PV system is increased remarkably during last few years. Now the capacity of solar PV electric system in the country is 25 MW (Table 6). At present the potential demand of power is 5569 MW, whereas, the supply of power is below 4000 MW. This led the energy starving for the country.

Table 3
Renewable energy indicators.

Indicator	Existing capacity at end of 2009
Power generation (GW)	
Hydropower	980
Wind power	159
Biomass power	54
Solar PV, grid-connected	21
Geothermal power	11
Concentrating solar thermal power (CSP)	0.6
Ocean (tidal) power	0.3
Hot water/heating (GWth)	
Biomass heating	270
Solar collectors for hot water/space heating	180
Geothermal heating	60
Transport (billion liters/year)	
Ethanol production	76
Biodiesel production	17
Rural off-grid energy (million)	
Biomass cooking stoves in use	570
Household-scale biogas digester in use	21
Household-scale solar PV system in use	2.4

Source: [4,5,24].

3.3. GHG emission

The per capita CO_2 emission of Bangladesh is very low. The CO_2 emission is increased from 0.1374 tonne/capita in 1990 to 0.2667 tonne/capita in 2006 (Fig. 2). This figure is much lower compared developed country like Qatar 56.2 tonne/capita and USA 19.0 tonne/capita in 2006 [9]. The CO_2 emission from different commercial fuel use is estimated as 22.52 million tonne (CO_2) from gas use and 10.74 million tonne from diesel use in 2008. The total CO_2 emission estimated is 35.22 million tonne in 2008 and this emission is increased to 36.36 million tonne in 2009 (Table 7). As per the report of MDG, the total CO_2 emission is estimated to be 37.82 million tonne in 2006 [10], whereas, the total CO_2 emission was estimated to be 13.44 million tonne in 1990 [3] and 14.42 million tonne in 1995 [11]. The primary source of CO_2 is petroleum products, which contributed 50% of all CO_2 emission and. Natural gas contributed 44% of total CO_2 emission during

Table 4
Final energy production scenario of Bangladesh.

Energy sources	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007
Gas (million m^3)	11,087	11,926	12,821	13,783	14,921	15,920
Petroleum ('000' million tonne)[a]	3311	3557	3521	3762	3651	–
Coal ('000' million tonne)[a]	620	211	213	0.4	0.3	–
Coal production from Barapukuria during 2008–2009 ('000' million tonne)	109					
Hydropower (GWh)	680	837	803	868	934	950

Source: [6].
[a]Imports.

Table 5
Final energy consumption scenario of Bangladesh.

Energy sources	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007
Gas (million m^3)	10,324	11,346	12,106	12,921	14,020	15,185
Petroleum ('000' million tonne)[a]	3315	3399	3657	3768	3782	–
Coal ('000' million tonne)[a]	638	229	261	74.4	–	–
Hydropower (GWh)	680	837	803	868	934	950

Source: [6]
[a]Imports.

Table 6
Electricity generation from different sources in Bangladesh (2009–2010).

Fuel type	Installed capacity (MW)	Share in percentage	Generation (GWh/year)	Share in percentage
Gas	4822	82.81	22661	88.44
Diesel	186	3.19	520	2.03
Coal	250	4.30	1030	4.02
Furnace oil	335	5.75	996	3.89
Hydropower	230	3.95	414	1.62
Total	5823	100	25621	100
Off-grid electricity development				
Solar PV	25	36.5		
Wind	1.9	Not recorded		
Biomass	250 kW	Not recorded		

Source: [7,8,25].

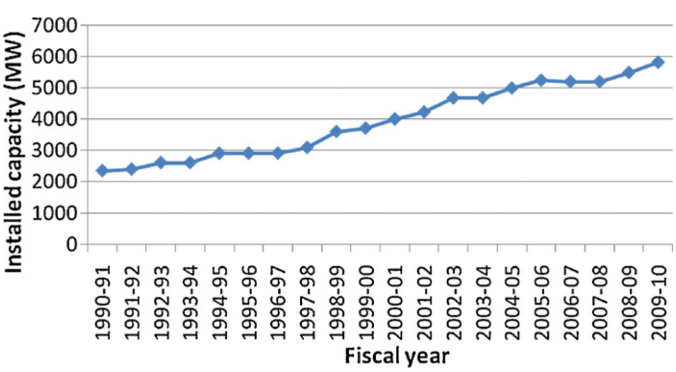


Fig. 1. Electric power capacity development in Bangladesh [7,25].

Table 7
Direct and indirect greenhouse gas emission from energy sector in Bangladesh.

Fuel type	CO_2 emission during 2007–2008 (million tonne)	CO_2 emission during 2008–2009 (million tonne)
Gas	22.52	23.53
Diesel	10.74	10.96
Furnace oil	0.97	0.89
Coal	0.99	0.98
Total	2034.22	2035.36

Source: [12,13] for emission factors.
Emission factors: natural gas, 51 kg CO_2/GJ for thermal and 0.599 kg CO_2/kWh for electricity; fuel oil, 73 kg CO_2/GJ for thermal and 0.893 kg CO_2/kWh for electricity; coal, 88 kg CO_2/GJ for thermal and 0.955 kg CO_2/kWh for electricity.

1977–1995. However, during 2008–2009, petroleum product contributed 36% and natural gas 64% of CO_2 emission.

4. Renewable energy in Bangladesh

4.1. Hydropower

Microhydro and minihydro have limited potential in Bangladesh, with the exception of Chittagong and the Chittagong Hill tracts. Hydropower assessments have identified some possible sites from 10 kW to 5 MW but no appreciable capacity has yet been installed. There is one hydro power plant at Kaptai

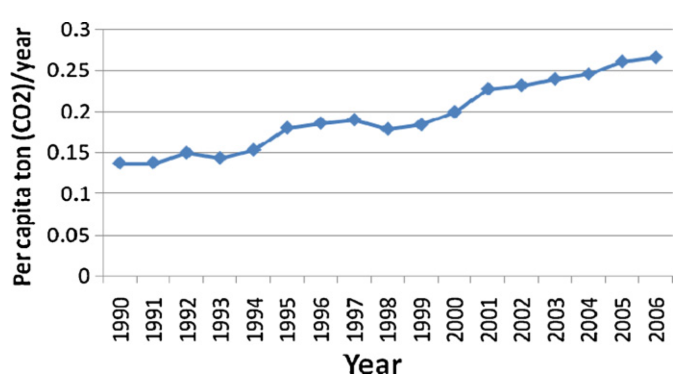


Fig. 2. Per capita CO_2 emission in Bangladesh [10].

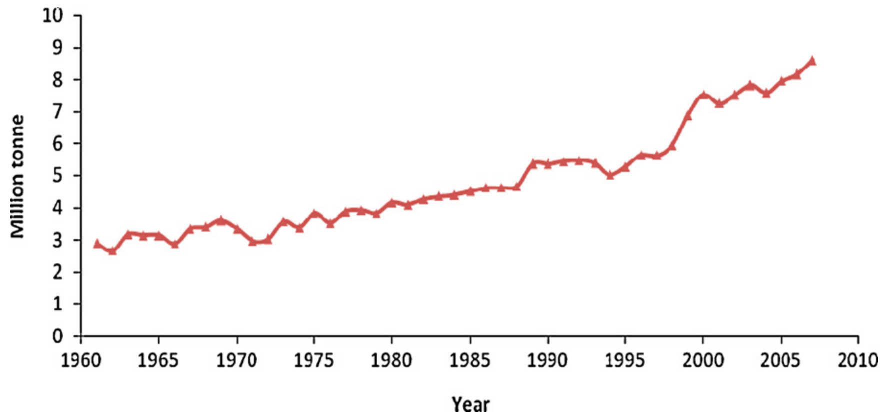


Fig. 3. Rice husk production scenario in Bangladesh [6,27,28].

established in the 1960s with installed capacity of 230 MW. The potential of micro hydropower plant sites and capacities are shown in Table 8.

4.2. Biomass

Biomass is by far the significant energy source in Bangladesh, approximately accounting for 48% of the country's total energy consumption [6]. More common biomass resources available in the country are rice husk, crop residue, wood, jute stick, animal waste, municipal waste, sugarcane bagasse, etc. The major industrial biomass is used in rice processing sector. A huge amount of thermal energy is needed to parboil and dry to process 30 million tonne of rice. Bangladesh produces about 6.62 million tonne of rice husk energy. The biomass energy supply is shown in Table 9. Biogas mainly from animal and municipal wastes may be one of the promising renewable energy resources for Bangladesh.

4.2.1. Rice husk energy for rice processing

Bangladesh has been producing a significant amount of rice husk food grains for the last four decades as shown in Fig. 3. The rice husk production has been also increased as the rice food grain is produced increasingly for the increased population of the country. The rice husk production increased from 3 million tonne in 1972 to approximately 9 million tonne in 2009. The growth rate of rice production was calculated to be 2.35% [6,27,28]. This bulk amount of rice husk is used mainly for process energy for rice parboiling. Share of rice husk energy used for rice parboiling is shown in Fig. 4. In Bangladesh, the annual estimated rice husk energy is consumed about 60 million GJ for drying and parboiling of 40 million tonne of paddy in 2010. This amount will increase to 92.5 million GJ in 2030 of rice husk for rice processing in Bangladesh [29]. Therefore biomass from agri-residues is playing a vital role for economic development of Bangladesh. GHG gas emission from rice husk is about 6.5 million tonne in 2010 and this emission will increase to about 11 million tonne in 2030. The GHG emission from rice processing sector is renewed within a short period during next growing season of rice plant ensuring sustainable environment (Fig. 5).

Table 8
Micro hydropower potential in Bangladesh.

Site	Estimated average discharge (l/s)	Available head (m)	Output power (kW)
Sailopropat Banderban	100.0	6.0	3.0
Madhabkundu, Moulovibazar	150.0	10.0	7.5
Faizlake	42.5.0	12.0	2.5
Chota Karina chara	311.0	6.0	9.3
Ringuli chara	340.0	4.6	7.8
Sealock	1132.0	9.0	51.0
Longi chara	425.0	3.0	6.4
Budia chara	170.0	7.6	6.5
Nikhari chara	480.0	6.8	16.3
Madhab chara	996.0	9.9	49.0
Total			159.3

Source: [14].

4.2.2. Biomass briquette

Biomass fuels are using beyond their regenerative limits due to high pressure of population. There is a severe shortage of wood fuel in Bangladesh amounting 2.1 million m^3 [16]. The estimated total cooking fuel requirement of Bangladesh was about 36.5 million tonne [17]. Only 7.5 million tonne of wood fuel is available. Bangladesh is facing problem with the deforesting process due to lack of fuel in small cities, public centers, small entrepreneur, tea stall, restaurants and rural areas. To meet this increasing energy demand people collect the wood fuel form the forest. There is only 6% dense forest of total area of Bangladesh. Presently the deforestation rate is 4 ha/h [18]. Waste biomass could be a viable alternative option to wood fuel. The main problem of waste biomass is its low bulk density as well as this traditional energy is not in an organized form. Biomass briquetting process can transform this biomass into solid, high bulk density, regular shape which can be easily stored and transported. This briquette fuel is dry woody material and its calorific value range from 14.2 to 17.5 MJ/kg and it is equivalent to "B" grade coal in terms of calorific value [19]. It burns slowly with less smoke than wood fuel. Therefore, there is a potential to replace the wood fuel with this biomass fuel from wastes. Rice husk briquette fuel is very much popular in some area of Bangladesh. The production of rice husk briquette in some areas of the country is shown in Fig. 6. It is reported from the comparison study of performance of the fuel wood and rice husk briquette that 1 kg of rice husk briquette could provide the same service obtained from 1.63 to 1.67 kg of fuelwood [17,20]. At present, about 1.11 million tonne of rice husk is available in Bangladesh for making briquette fuel [22]. From this amount of husk about 1.0 million tonne of briquette fuel could be produced. Annual saving of CO_2-equivalent from the use of 1.0 million tonne of rice husk briquette would be 1.82 million tonne of CO_2-equivalent from which the country could earn US$21.84 million annually. A case study of Mymensingh showed that 16.42×10^3 tonne of CO_2-equivalent would be saved by using rice husk briquette fuel instead of wood fuel that is equivalent to US$$197.04 \times 10^3$ annual worth (Table 10).

Table 9
Estimated biomass energy supply in Bangladesh (million tonne).

Fuel type	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005
Cowdung	8.2	8.2	8.2	8.3	8.4
Jute stick	2.2	2.3	2.2	2.1	2.0
Rice straw	18.75	18.49	18.60	18.60	18.50
Rice husk	6.4	6.5	6.6	6.5	6.5
Bagasse	1.3	1.4	1.4	1.5	1.5
Firewood	6.2	6.4	6.6	7.2	7.8
Twigs and leaves	3.1	3.1	3.2	3.2	3.2
Other wastes	2.8	2.9	3.0	3.1	3.2
Total	48.95	49.29	49.80	50.50	51.20

Source: [6].

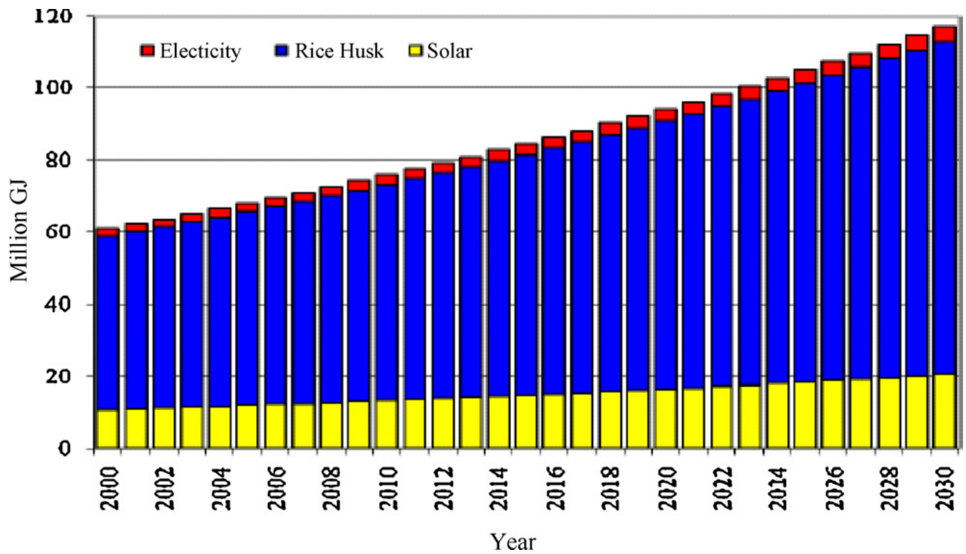


Fig. 4. Biomass energy share for rice processing in Bangladesh [29].

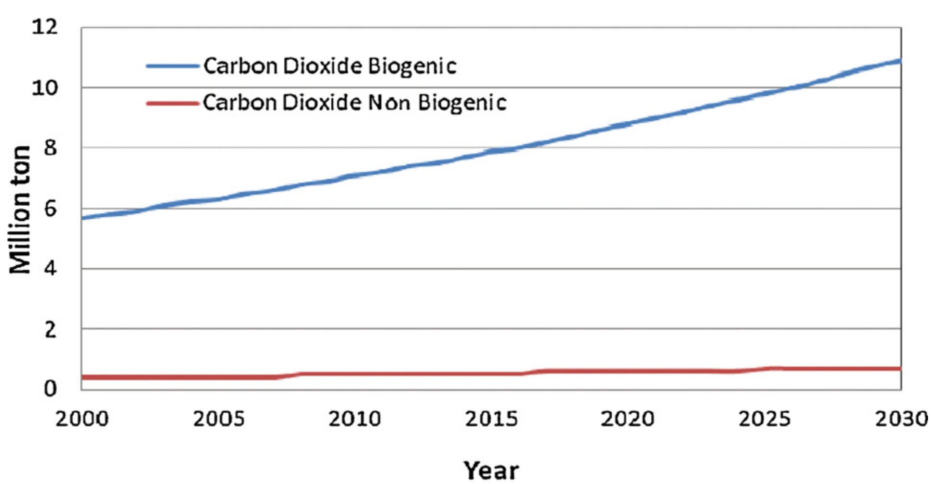


Fig. 5. GHG emission reduction by using biomass energy for rice processing [29].

Table 10
Global emission CO_2 saving with biomass briquette fuel options over wood fuel in Mymensingh town.

Option	Annual demand ($\times 10^6$)	CO_2 equivalent ($\times 10^3$ tonne/annum)	Net CO_2 saving over wood fuel ($\times 10^3$ tonne/annum)	Return from CO_2 abatement ($\times 10^3$ US$/annum)
Wood fuel	14.244 kg	17.370	–	–
Rice husk briquette fuel	9.039 kg	0.954	16.42	197.04

Source: [21].
CO_2 reduction trade, US$ 12.00/tonne.

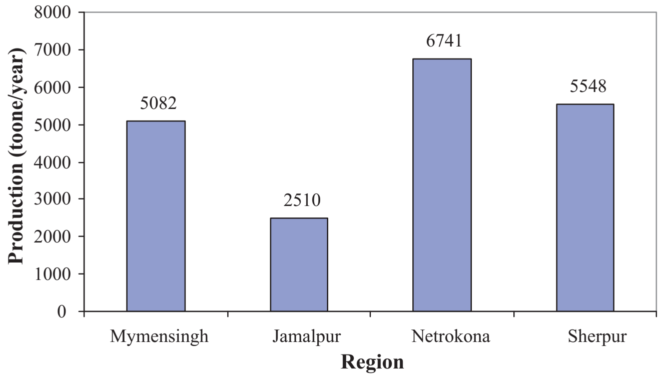


Fig. 6. Production of rice husk briquette fuel in selected areas of Bangladesh [20].

Table 11
Monthly global solar insolation at different cities of Bangladesh (kWh/m^2/day).

Month	Dhaka	Rajshahi	Sylhet	Bogra	Barishal	Jessore
January	4.03	3.96	4.00	4.01	4.17	4.25
February	4.78	4.47	4.63	4.69	4.81	4.85
March	5.33	5.88	5.20	5.68	5.30	4.50
April	5.71	6.24	5.24	5.87	5.94	6.23
May	5.71	6.17	5.37	6.02	5.75	6.09
June	4.80	5.25	4.53	5.26	4.39	5.12
July	4.41	4.79	4.14	4.34	4.20	4.81
August	4.82	5.16	4.56	4.84	4.42	4.93
September	4.41	4.96	4.07	4.67	4.48	4.57
October	4.61	4.88	4.61	4.65	4.71	4.68
November	4.27	4.42	4.32	4.35	4.35	4.24
December	3.92	3.82	3.85	3.87	3.95	3.97
Average	4.73	5.00	4.54	4.85	4.71	4.85

Source: [15].

4.3. Solar energy

Bangladesh is situated between 20.30° and 26.38° north latitude and 88.04° and 92.44° east longitude, is an ideal position for solar energy harnessing. The ranges of solar radiation are between 4 and 6.5 kWh/m^2/day (Table 11). The bright sunshine hours varies from 6 to 9 h/day (Table 12). Solar photovoltaic (PV) systems are in use throughout the country with over 300,000 household-level installations having capacity of about 25 MW (July 2009). So far in Bangladesh the solar electricity being produced from solar PV panels, which includes, solar home system, centralized (AC) system, centralized (AC) market electrification, water pumping, rural clinic, roof top PV mini-grid system, telecommunications, railway signaling, refrigeration, cyclone shelters, etc., ICT training centers, community places, etc. By the 2012 one million households will be powered form solar PV panel and targeted to produce 50 MW power [8]. Scaling-up of solar PV systems assisted by the development partners are being implemented through the Rural Electrification Board (REB), Local Government Engineering Department (LGED), Bangladesh Power Development Board (BPDB) and other agencies implementing solar energy program. Renewable Energy Research Centre of the University of Dhaka has installed a model 1.1 kW grid connected photovoltaic system. There is a strong potential for solar energy within the country. Solar thermal power/concentrating solar power (CSP): the technology involves harnessing solar radiation for generation of electricity through a number of steps finally generating mechanical energy to run a generator. This technology needs to be disseminated in the country to supplement the power supply.

Table 12
Average bright sunshine hours at Dhaka city (average period 1961–1980).

Month	Daily mean	Maximum	Minimum
January	8.7	9.9	7.5
February	9.1	10.7	7.5
March	8.8	10.1	7.5
April	8.9	10.2	7.8
May	8.2	9.7	5.7
June	4.9	7.3	3.8
July	5.1	6.7	2.6
August	5.8	7.1	4.1
September	6.0	8.5	4.8
October	7.6	9.2	6.5
November	8.6	9.9	7.0
December	8.9	10.2	7.4
Average	7.55	9.13	6.03

Source: [8].

Table 13
Wind energy potential at selected sites of Bangladesh.

Station name	Height (m)	Mean velocity (m/s)	Energy density (kW/m^2)
Engineering Staff Collenge, Munshiganj	20	3.54	0.0588
BIT Campus, Chittagong	20	1.75	0.0129
Sitakundu	20	2.30	0.0449
Khagrachari	20	1.18	0.0140
Kutubdia	20	3.57	0.0572
Kuakata	20	4.18	0.0901
Pakshey	20	2.77	0.0338
Naogaon	20	1.92	0.0148
Panchagarh	20	1.44	0.0118
Kishoreganj	20	2.24	0.0194

4.4. Wind energy

Wind energy has also made some inroads, but its potential is likely more limited to coastal areas islands with strong wind regimes. Although these coastal settings afford good opportunities for wind powered pumping and electricity generation, the problem of monsoon winds (March–October) exceeding the design parameters of most any wind machine must be addressed. Additional work is needed on technical requirements and opportunities for wind power in monsoonal regions, as extensive wind development has taken place in India (e.g., Tamil Nadu), where conditions similar to Bangladesh can be found. Presently there are 1.9 MW of installed wind turbines operating in Bangladesh, notably at Feni and Kutubdia. The potential sites of wind power and energy output per square meter are shown in Table 13.

5. Mitigation of GHG emission

The low GHG emission status of Bangladesh however provides no relief from the global warming effects because 1.0 m rise in sea level would inundate an area of 22,000 km^2 of Bangladesh, affecting 17 million people. The other impacts of global warming would include agriculture, bio diversity and forestry, human health, fisheries, drainage, etc. This is very high time to take neccesary action to mitigate GHG emission. Renewable energy is the key solution for mitigation of GHG gas emission as well as sustainable development. Bangladesh is now using biomass energy as main source of renewable energy. Biomass consumption in rice processing sector makes a sustainable carbon dioxide cycle. Rice husk briquette fuel is being used as alternative of wood fuel. The replacement of wood fuel by briquette fuel ensures the sustainable growth of forest and

enrich carbon sink as well. Use of biomass energy in an efficient way can contribute to mitigate GHG emissions from fossil fuel. Biogas is being used as cooking fuel in rural areas and for producing electricity in a small scale in some rural and peri-urban areas. Solar home system for lighting at night in rural areas is being used and the use of solar photovoltaic is increasing and replaces kerosene fuel. The magnitude of total installation of solar photovoltaic is about 25 MW a remarkable success story of Bangladesh.

6. Conclusion

At present the potential demand of power is 5569 MW and the supply is below 4000 MW. The country is dependent on the imported petroleum that is big burden on the economy. To meet the extra demand of power people are trying to use the electricity from solar PV, but the country economic situation could not permit for extensive of solar electricity at this moment. The total capacity of solar electricity is 25 MW. The per capita emission is only 0.2667 tonne (CO_2) per year that is still much below the world leading countries. However, Bangladesh is one of the most vulnerable countries to climate change effect in the world. In this regard, renewable energy resources appear to be the one of the most efficient and effective solution for clean and sustainable energy development in Bangladesh. Biomass is dominating to meet the rural energy in the country. The geographical location of Bangladesh has several advantages for extensive use of grid connected solar electricity and stand alone solar PV system. This article presents a review of the potential and utilization of the renewable energy sources in Bangladesh.

References

[1] Yuksel I. Global warming and renewable energy sources for sustainable development in Turkey. Renew Energy 2008;33:802–12.
[2] IEA, International Energy Agency. Beyond Kyoto: energy dynamics and climate stabilization. Paris: OECD/IEA; 2002. Available from http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=1096 [accessed 21.02.11].
[3] Global climate change: Bangladesh episode. Dhaka: Department of Environment, Ministry of Environment and Forest; 1997.
[4] REN21, Renewable Energy Policy Network for 21st Century, Renewables Global Status Report 2005 updates. Available from http://www.ren21.net/publications/default.asp [accessed 10.09.09].
[5] REN21, Renewable Energy Policy Network for 21st Century, Renewables Global Status Report 2009 updates. Available from http://www.ren21.net/publications/default.asp [accessed 10.09.09].
[6] BBS, Bangladesh Bureau of Statistics. Planning Division, Ministry of Planning. Government of the People's Republic of Bangladesh; 2008.
[7] BPDB, Bangladesh Power Development Board. Annual Report 2007–2008.
[8] http://www.reein.org [accessed 10.09.09].
[9] http://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions_percapita [accessed 14.09.09].
[10] MDG Country Report 2009. http://mdgs.un.org/unsd/mdg/Data.aspx [accessed 13.09.09].
[11] Azad KA, Nashreen SW, Sultana J. State of energy consumption and CO_2 emission in Bangladesh. R Swed Acad Sci Ambio 2006;35(2):86–8.
[12] Fridleifsson IB, Bertani R, Huenges E, Lund JW, Ragnarsson A, Rybach L. The possible role and contribution of geothermal energy to the mitigation of climate change. In: Hohmeyer O, Trittin T, editors. IPCC scoping meeting on renewable energy sources, proceedings. 2008. p. 59–80.
[13] Hanova J, Dowlatabadi I. Strategic GHG reduction through the use of ground source heat pump technology. Environ Res Lett 2007;2:8, doi:10.1088/1748-9326/2/4/044001.
[14] Sadrul Islam AKM, Islam MQ, Hossain ZH, Khan MI, Uddin SA. Appropriate low head micro hydro system for Bangladesh. In: Second international conference on electrical and computer engineering ICECE. 2002. p. 216–9. ISBN: 984-32-0328-3.
[15] Shahida R, Department of Applied Physics, Dhaka University, recorded from 1988 to 1998, Available from http://www.reein.org [accessed 10.09.09].
[16] RWEDP, Regional Wood Energy Development Programme.Report training workshop: integrating wood fuel production into the implementation of agriculture forestry and rural extension programs. 1995.
[17] Miah MAK, Baqui MA, Huda MD, Uddin MN. Rice husk briquette as alternative fuel in Bangladesh. AMA Japan 1999;30(2):63–8.
[18] The daily Janakantha. Janakontha Bhaban, Dhaka, Bangladesh. Available from www.janakantha.com/p1/ln.pdf; 2005 [accessed 02.06.05].
[19] Moral MNA, Rahman ANMM. Briquetting activities in Bangladesh. In: Proceedings of training workshop on renewable energy education and application for rural communities in Bangladesh. 1999. p. 368–79.
[20] Ahiduzzaman M. Sustainablility of biomass energy development technology (densification) in Bangladesh. Int J BioRes 2006;1(2):40–6.
[21] Ahiduzzaman M, Sadrul Islam AKM. Environmental impact of rice husk Briquette fuel use in Bangladesh: a case study of Mymensingh. In: 1st international conference on the developments in renewable energy technology (ICDRET'09). 2009.
[22] Ahiduzzaman M, Baqui MA, Kamruzzaman M, Dasgupta N. Prospect of rice husk briquette fuel in Bangladesh. J Agric Eng IEB 2008;35/AE:57–63.
[23] EIA, Energy Information Administration. International Energy Outlook 2010. Available from www.eia.doe.gov/oiaf/ieo/pdf/emissions.pdf [accessed 8.02.11].
[24] REN21, Renewable Energy Policy Network for 21st Century. Renewables Global Status Report 2010 updates. Available from http://www.ren21.net/REN21Activities/Publications/GlobalStatusReport/tabid/5434/Default.aspx [accessed 16.02.11].
[25] http://www.bpdb.gov.bd/key_statistics.htm [accessed 17.02.11].
[27] http://www.irri.org/science/ricestat/pdfs/WRS2005-Table 01.pdf [accessed 03.02.06].
[28] http://faostat.fao.org/site/339/default.aspx [accessed 17.02.11].
[29] Ahiduzzaman M, Sadrul Islam AKM, Energy utilization and environmental aspects of rice processing industries in Bangladesh. Energies 2009;2:134–49, doi:10.3390/en20100134.